REVIEW OF INFORMATION RELATING TO POSSIBLE CRITICAL HABITAT FOR EASTERN NORTH PACIFIC RIGHT WHALES

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INTRODUCTION

North Pacific right whale: overview of biology, hunting history & present status

The North Pacific right whale is a member of the family Balaenidae and is closely related to the right whales that inhabit the North Atlantic and the Southern Hemisphere.[1] Right whales are large baleen whales which grow to lengths and weights exceeding 18 meters and 100 tons, respectively. They are filter feeders whose prey consists exclusively of zooplankton (notably copepods; see below). Right whales attain sexual maturity at an average age of 8-10 years, and females produce a single calf at intervals of 3-5 years (Kraus *et al.* 2001). Their life expectancy is unclear, but is known to reach 70 years in some cases (Hamilton *et al.* 1998, Kenney 2002).

Right whales are generally migratory, with at least a portion of the population moving between summer feeding grounds in temperate or high latitudes and winter calving areas in warmer waters (Kraus *et al.* 1986, Clapham *et al.* 2004). In the North Pacific, the feeding range is known to include the Gulf of Alaska, the Aleutian Islands, the Bering Sea and the Sea of Okhotsk. Although a general northward movement is evident in spring and summer, it is unclear whether the entire population undertakes a predictable seasonal migration, and the location of calving grounds remains completely unknown (Scarff 1986, Scarff 1991, Brownell *et al.* 2001, Clapham *et al.* 2004, Shelden *et al.* 2005). Further details of occurrence and distribution are provided below.

Worldwide, right whales were probably the first of the great whales to be hunted on a regular basis for commercial profit, beginning with the Basque fishery in the Bay of Biscay in the 11th century (Aguilar 1986). North Atlantic right whales were extensively depleted throughout their range, and a remnant population in the eastern North Atlantic was all but extirpated by whaling off Scotland and Iceland at the turn of the 20th century (Clapham *et al.* 1999).

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[1]The taxonomic status of right whales worldwide has recently been revised in light of genetic analysis (see Rosenbaum *et al.* 2000, Gaines *et al.* 2005). Applying a phylogenetic species concept to molecular data separates right whales into three distinct species: *Eubalaena glacialis* (North Atlantic), *E. japonica* (North Pacific) and *E. australis* (Southern Hemisphere). The National Marine Fisheries Service formally recognized this distinction for the purpose of management in a final rule published in April 2003 (68 FR 17560), but subsequently determined that the issuance of this rule did not comply with the requirements of the Endangered Species Act (ESA), and thus rescinded it (70 FR 1830) prior to beginning the process anew. As of the time of writing, North Atlantic and North Pacific right whales are thus both officially considered to be "northern right whales" (*Balaena glacialis*) under the ESA; however, the latter are referred to here as *E. japonica* given the wide acceptance of this taxon in both the scientific literature and elsewhere (e.g. by the International Whaling Commission).

In the North Pacific, whaling for right whales began in the Gulf of Alaska (known to whalers as the "Northwest Ground") in 1835 (Webb 1988). By 1849, right whales were sufficiently depleted in the eastern North Pacific such that many whalers turned their attention to newly discovered stocks of bowhead whales (*Balaena mysticetus*) in the Arctic. Right whales were extensively hunted in the western North Pacific in the latter half of the 19th century, and by 1900 were scarce throughout their range.

Right whales were protected worldwide in 1935 through a League of Nations agreement. However, because neither Japan nor the USSR signed this agreement both nations were theoretically free to continue right whaling until 1949, when the newly-created International Whaling Commission endorsed this ban. Following this, a total of 23 North Pacific right whales were legally killed by Japan and the USSR under Article VIII of the International Convention for the Regulation of Whaling (1946), which permits the taking of whales for scientific research purposes. However, it is now known that the USSR illegally caught many right whales in the North Pacific (Doroshenko 2000, Brownell *et al.* 2001). In the eastern North Pacific, 372 right whales were killed by the Soviets between 1963 and 1967; of these, 251 were taken in the Gulf of Alaska south of Kodiak, and 121 in the southeastern Bering Sea. These takes devastated a population that, while undoubtedly small, may have been undergoing a slow recovery (Brownell *et al.* 2001).[2]

As a result of this historic and recent hunting, right whales in the North Pacific today are among the most endangered of all whales worldwide. Right whales were listed in 1970 following passage of the Endangered Species Conservation Act (ESCA) of 1969, and automatically granted endangered status when the ESCA was repealed and replaced by the Endangered Species Act (ESA) of 1973. Right whales were also protected in U.S. waters under the Marine Mammal Protection Act of 1972. The National Marine Fisheries Service (NMFS) issued a Recovery Plan for the northern right whale in 1991 which covered both the North Atlantic and North Pacific (NMFS 1991). Brownell *et al.* (2001) noted that there was no evidence for exchange between the western and eastern Pacific, and that the two populations had different recovery histories; consequently, they argued that these stocks should be treated as separate for the purpose of management, a division which has been duly recognized by NMFS in Stock Assessment Reports (Angliss and Lodge 2004).

In the western North Pacific (the Sea of Okhotsk and adjacent areas), current abundance is unknown but is probably in the low to mid-hundreds (Brownell *et al.* 2001). There is no estimate of abundance for the eastern North Pacific (Bering Sea, Aleutian Islands and Gulf of Alaska), but sightings are rare; most biologists believe the current population is unlikely to exceed a hundred individuals, and is probably much smaller. Prior to the illegal Soviet catches of the 1960's, an average of 25 whales were observed each year in the eastern North Pacific (Brownell *et al.* 2001); in contrast, the total number of records in the 35 years from 1965 to 1999 was only 82, or 2.3 whales per annum.

Since 1996, NMFS and other surveys (directed or otherwise) have detected small numbers of right whales in the southeastern Bering Sea, including an aggregation estimated at 24 animals in the summer of 2004. Photo-identification and genetic data have identified 17 individuals from the Bering Sea, and the high inter-annual resighting rate further reinforces the idea that this population is small. However, the number of animals

[2]In the western North Pacific, 136 right whales are known to have been illegally caught in the Okhotsk Sea and the Kurile Islands in 1967 and 1971 (Doroshenko 2000).

using habitats other than the Bering Sea is not known.

Critical Habitat Designation: History

Critical Habitat (CH) is defined under Section 7(a)(2) of the ESA as:

> *the specific areas within the geographical area occupied by the species, at the time it is listed... on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection*.

CH was designated for North Atlantic right whales in 1994. In October 2000, NMFS was petitioned by the Center for Biological Diversity to designate CH for North Pacific right whales. In February 2002, NMFS announced its decision that CH could not be designated at that time because the essential biological requirements of the population were not sufficiently understood. However, in June 2005, a federal judge found this reasoning invalid and ordered the agency to publish a proposed rule designating CH by 28th October 2005. As a result of this order, we here review information to assist in an assessment of which areas may represent CH for right whales in the eastern North Pacific. Because the waters of the western North Pacific are not under U.S. jurisdiction, we do not consider CH for the separate population in that region.

CRITICAL HABITAT: REVIEW OF RELEVANT INFORMATION

Critical Habitat is defined based upon the existence of Primary Constituent Elements (PCEs). These must be tangible, recognizable and measurable features of the environment that are essential for the conservation of the species in question. We consider the PCEs involved with right whales to be their prey (large species of copepods), as detailed below.

In the following sections, we first review the designation of CH for North Atlantic right whales, then summarize available information for the North Pacific regarding the distribution of right whales, their prey and the factors which promote the prey's abundance and aggregation. At various points in this document we apply knowledge gained from demographic and ecological investigations of the well-studied North Atlantic right whale to gain perspective on the behavior and habitat requirements of right whales in the North Pacific. Although as noted above these are widely regarded as separate species, they are very similar in their general biology and behavior, notably in the prey characteristics which determine their high-latitude distribution.

Basis of CH designation for North Atlantic right whales

As noted above, CH for North Atlantic right whales was designated by a NMFS final rule published in June 1994 (59 FR 28793). The three areas for this designation were defined primarily using the distribution of right whales, although the final rule noted that the two feeding grounds identified as CH (the Great South Channel and Cape Cod Bay) were characterized by abundant prey resources and by physical features which promoted biological productivity and/or the aggregation of copepods. Thus the final rule recognized the concept of PCEs as based upon the best scientific information available at the time (Pace and Merrick 2005).

The boundaries of CH for the North Atlantic right whale were drawn to encompass 90% of the recorded sightings in the areas concerned.

North Pacific Right Whale Distribution

We begin this section with a general description of right whale distribution in historical times as well as at the time the species was listed as endangered, and we consider whether the present range is likely to be significantly different from the latter. A listing of all 20th century records of North Pacific right whales was presented by Brownell *et al.* (2001), and those data were mapped by month (together with 19th century records) by Clapham *et al.* (2004). A detailed assessment of the features and areas important to right whales in the Bering Sea and Gulf of Alaska was recently reviewed by Shelden *et al.* (2005); that publication is of particular importance to our assessment here, and their findings are summarized later in this document.

Historical distribution

Prior to the onset of commercial whaling in 1835, right whales were widely distributed across the North Pacific (Scarff 1986, Clapham *et al.* 2004, Shelden *et al.* 2005). In the eastern North Pacific, the waters adjacent to the Aleutian Islands and much of the Bering Sea below 60^{o} N were major feeding grounds during spring, summer and autumn, as was virtually the entire Gulf of Alaska. Neither the historical nor present-day breeding/calving grounds for this population have ever been identified. Historical distribution as derived from whaling ship logbook abstracts by Maury (1853 *et seq.*) and Townsend (1935) is given in Clapham *et al.* (2004) and Shelden *et al.* (2005).

Distribution at the time of listing, and at present time

As noted by Clapham *et al.* (2004), the current range of right whales in the North Pacific is likely considerably diminished relative to the situation during the peak period of whaling in the 19th century. However, too little sighting effort has been expended to delineate which (if any) areas have been abandoned, or not yet rediscovered, by the extant population.

Northern right whales were listed under the ESA in 1973, and under the precursor to this Act (the ESCA) in 1970. Thus, for the purpose of this analysis the "time of listing" is considered to be 1970. This was after the occurrence of the large illegal Soviet catches in the Bering Sea and Gulf of Alaska (1963-1967).

Sightings of right whales since World War II are shown in Figure 1 (1941-1968) and Figure 2 (1979-2004); with the exception of a few Japanese sightings for which exact positions do not exist, there are no records from 1969 to 1978, and thus none from the actual year of listing. However, there is no reason to suspect that the animals that remain alive today are inhabiting a substantially different range than whales alive during the time of the Soviet catches; indeed, given the longevity of this species, it is likely that some of the individuals who survived that whaling episode remain extant now. Consequently, recent habitat use is unlikely to be different from that at or before the time of listing. As a result, all post-war sightings data have been combined (see Figure 3) for subsequent analysis herein.

Both the southeastern Bering Sea and the western Gulf of Alaska (shelf and slope waters south of Kodiak) have been the focus of many sightings (as well as the illegal Soviet catches) in recent decades. Recent acoustic detections of right whale calls have been made in both areas using autonomous recording packages deployed for extended periods; these data are shown in Figure 2 (as star symbols over the respective acoustic sighting). They confirm the presence of right whales in the southeastern Bering Sea from May into November; records from the Gulf of Alaska are somewhat more sporadic, but include detections in August and September.

Seasonal movements are evident in the 20th century data, with a general northward migration into the Gulf of Alaska and Bering Sea in spring and summer, and a gradual movement away from these areas in autumn (Clapham *et al.* 2004, Shelden *et al.* 2005). There are very few records of right whales anywhere in the North Pacific in winter.

Distribution Overview

In general, the majority of North Pacific right whale sightings (historically and in recent times) have occurred from about 40º N to 60º N. There are historical records from north of 60º N, but these are rare and are likely to be misidentified bowhead whales. Right whales have on rare occasions been recorded off California and Mexico, as well as off Hawaii. However, as noted by Brownell *et al.* (2001), there is no evidence that either Hawaii or the west coast of North America from Washington State to Baja California were ever important habitats for right whales; given the amount of whaling effort as well as the human population density in these regions, it is highly unlikely that substantial concentrations of right whales would have passed unnoticed. Furthermore, there is no archaeological evidence from the U.S. west coast suggesting that right whales were the target of local native hunts. Consequently, the few records from this region are considered to represent vagrants.

Recent data indicate that while the present range of the remnant population is likely reduced relative to pre-whaling times, the southeastern Bering Sea and western Gulf of Alaska (south of Kodiak) remain important and commonly utilized habitats. Consequently, they are the focus of the CH discussion presented here.

Prey and habitat characteristics

Shelden *et al.* (2005) reviewed prey and habitat characteristics of North Pacific right whales. They noted that habitat selection is often associated with features that influence abundance and availability of a predator's prey. Right whales in the North Pacific are known to prey upon a variety of zooplankton species including *Calanus marshallae, Euphausia pacifica, Metridia* spp., and copepods of the genus *Neocalanus* (Omura 1986). *C. marshallae* was only recently recognized as a species distinct from *C. glacialis* (Frost 1974), and the species names are used interchangeably in the literature. Both of these species were once referred to as *C. finmarchicus*, the principal prey of North Atlantic right whales (Baumgartner and Mate 2003, Baumgartner *et al.* 2003a,b). North Atlantic right whales require dense prey aggregations (minimum prey patch concentrations >3000 copepods m^{-3}) to forage efficiently (Baumgartner and Mate 2003); Mayo (unpublished data) has recorded densities exceeding 1,000,000 organisms m^{-3} next to feeding right whales in Cape Cod Bay, Massachusetts. Given this, and the ecological similarity of right whales worldwide, there is little doubt that availability of suitably dense prey also greatly influences the distribution of the small North Pacific population on their feeding grounds in the Southeastern Bering Sea (SEBS) and Gulf of Alaska (GOA).

Southeastern Bering Sea slope waters

The Bering Sea slope is a very productive zone, sometimes referred to as the 'Greenbelt', where annual primary production can exceed that on the adjacent shelf and basin by 60% and 270%, respectively (Springer *et al*. 1996). Physical processes at the shelf edge, such as intensive tidal mixing, eddies and up-canyon flow, bring nutrients to the surface thereby supporting enhanced productivity and elevated biomass of phytoplankton, zooplankton, and fish. This elevated productivity appears to influence whale distribution as well. For example, fin whales aggregate to feed along the Bering Sea slope, with densities an order of magnitude higher than on the adjacent middle-shelf (Moore *et al*. 2002). Recent studies of this dynamic habitat reveal the importance of cyclonic (anti-clockwise) and anticyclonic (clockwise) eddies to nutrient transport and patterns of meso-scale productivity (Okkonen 2001, Mizobata *et al*. 2002). These features are roughly 100-150 km in diameter and can pump nutrients to the surface from depths of 100 to 500 m. Specifically, very high chlorophyll α concentrations develop in the center of cyclonic and around the periphery of anticyclonic eddies, features that typically form at the intersection of the slope with the eastern Aleutian Islands and propagate northwestward along the Bering slope current (Okkonen 2001, Mizobata *et al.,* 2002). In the North Atlantic, right whales were associated with thermal fronts (Brown and Winn 1989), areas of upwelling along the continental shelf, and at least one satellite-tagged right whale fed along the edge of a warm-core eddy (Mate *et al.* 1997). Western North Pacific right whales have also been observed in association with oceanic frontal zones that produce eddies southeast of Hokkaido Island, Japan, and southeast of Cape Patience (Mys Terpeniya), Sakhalin Island, in the Okhotsk Sea (Omura *et al.* 1969). Whether or not the Bering Slope Current, or eddies shed from it, support production or entrain right whale prey is unknown.

From August to October in 1955 and 1956, Soviet scientists observed aggregations of *Calanus* between the Pribilof Islands and the Aleutian Islands (around 170ºW) that were

identified as *C. finmarchicus*, though, as mentioned above, were probably *C. marshallae* (Klumov 1963). Flint *et al.* (2002) also report high concentrations of *C. marshallae* at frontal zones near the Pribilof Islands, with especially high biomass noted for the subthermohaline layer. This oceanographic front effectively separates slope and outer shelf *Neocalanus* spp. from the inshore middle shelf community of *C. marshallae* (Vidal and Smith 1986). Right whales were found on both sides of this frontal zone (that coincides with the shelf break at 170 m) during both the 19th and 20th centuries. This is similar to the habitat described by Baumgartner *et al.* (2003a) for right whales feeding in the North Atlantic. Six right whales that were caught under scientific permit in late July-early August 1962-63 in Bering Sea slope waters had exclusively consumed *Neocalanus cristatus* (*Calanus cristatus*: Omura *et al.* 1969). Although oceanic species such as *Neocalanus* usually enter diapause and migrate to depths greater than 200m by late summer in the slope waters of the Bering Sea (Vidal and Smith 1986), right whales may still be able to utilize these resources by targeting regions where the bottom mixed layer forces the zooplankton into shallower, discrete layers (e.g. Baumgartner *et al.* 2003a).

Southeastern Bering Sea middle-shelf waters

The SEBS shelf has been the focus of intense oceanographic study since the late 1970s (e.g. Schumacher *et al*. 1979, Coachman 1986, Napp *et al.* 2000; Hunt *et al.* 2002a, Hunt *et al*., 2002b), largely due to the considerable commercial fishing effort in the area (National Research Council 1996). Coachman (1986) described the now well-established hydrographic domains of the inner-, middle- and outer-shelf, separated by a front or transition zone at roughly the 50 m (inner front) and 100 m (outer front) isobaths. During the 1990s, research focused on these domains demonstrated dynamic advection of nutrient-rich Bering slope water onto the shelf in both winter and summer, via eddies, meanders and up-canyon flow (Schumacher and Stabeno 1998, Stabeno and Hunt 2002). These intrusions of nutrient-rich water, physical factors related to water column stratification, and long summer day length results in a very productive food web over the SEBS shelf (e.g. Livingston *et al.*1999, Napp *et al.,* 2002, Coyle and Pinchuk, 2002; Schumacher *et al.,* 2003). Specifically, copepod species upon which right whales feed (e.g. *Calanus marshallae*, *Pseudocalanus* spp. and *Neocalanus* spp.) are among the most abundant of the zooplankton sampled over the middle shelf (Cooney and Coyle, 1982; Smith and Vidal, 1986). Small, dense patches (to > 500 mg/m^{-3}) of euphausiids (*Thysanoessa raschii, T. inermis*), potential right whale prey, have also been reported for waters near the SEBS inner front (Coyle and Pinchuk, 2002).

Zooplankton sampled near right whales seen in the SEBS in July 1997 included *C. marshallae*, *Pseudocalanus newmani*, and *Acartia longiremis* (Tynan, 1998). *C. marshallae* was the dominant copepod found in these samples as well as samples collected near right whales in the same region in 1999 (Tynan *et al.,* 2001). *C. marshallae* is the only “large” calanoid species found over the SEBS middle shelf (Cooney and Coyle, 1982; Smith and Vidal, 1986). Concentrations of copepods were significantly higher in 1994-98 than in 1980-81 by at least an order of magnitude (Napp *et al.,* 2002) and Tynan *et al.* (2001) suggest that this increased production may explain the presence of right whales in middle shelf waters. However, at least three right whales were observed in 1985 in the same location as the middle shelf sightings reported in the late 1990s (Goddard and Rugh, 1998),

and right whales have been present in middle shelf waters during all the time periods reviewed within this document. Therefore, the middle shelf is not a new habitat for right whales and consumption of *C. marshallae* does not constitute a change in prey selection.

Eastern Aleutian Islands

The area around the eastern Aleutians is an oceanographically dynamic zone. The primary currents run parallel to the coast and include the Alaska Coastal Current, the Alaskan Stream, the Aleutian North Slope Current and the Bering Sea Current. The Alaska Coastal Current is dominated by freshwater discharge and flows southwestward between 20-50 km of shore along the Alaska Peninsula and Aleutian archipelago, turning northward at passes between Unimak and Samalga Island (Royer *et al.* 1979, Ladd *et al.* in press). The Alaskan Stream also flows southwestward along the shelf break, approaching the archipelago as the shelf narrows west of Samalga Pass. Both the Aleutian North Slope Current and the Bering Sea Current flow eastward, north of the islands, the latter continuing northward. Flow through the passes of the eastern and central Aleutian Islands was the focus of an interdisciplinary study in 2001-02 (e.g. Ladd *et al.* in press, Stabeno *et al.* submitted). Although right whales were not seen during recent research cruises in this area (Sinclair *et al.* submitted), results indicate the eastern Aleutians are dynamic and productive, with dense patches of both copepod and euphausiid zooplankton reported within and at the margins of the passes (Coyle, in press). The importance of such passes as a source of *Neocalanus* spp. has been documented for western North Pacific right whales taken in waters adjacent to the Kuril Islands, Russia (Klumov, 1962).

Gulf of Alaska

The central GOA is dominated by the Alaskan gyre, a cyclonic feature that is demarcated to the south by the eastward flowing North Pacific Current and to the north by the AS and ACC, which flow westward near the shelf break. The bottom topography of this region is rugged and includes seamounts, ridges, and submarine canyons along with the abyssal plain. Strong semi-diurnal tides and current flow generate numerous eddies and meanders (Okkonen *et al*., 2001), that influence the distribution of zooplankton.

Copepods are the dominant taxa of mesozooplankton found in the Gulf of Alaska and are patchily distributed across a wide variety of water depths. Three large herbivorous species comprise more than 70% of the biomass: *N. cristatus*, *N. plumchrus*, and *Eucalanus bungii* (Cooney 1986, 1987). In northern GOA shelf waters, the late winter and spring zooplankton is dominated by calanoid copepods (*Neocalanus* spp.), with a production peak in May; a cycle that appears resistant to environmental variability associated with El Niño/Southern Oscillation (ENSO) (Coyle and Pinchuk, 2003). In oceanic waters (50ºN, 145ºW), *N. plumchrus* dominate (Miller and Nielsen 1988, Miller and Clemons 1988) and have demonstrated dramatic shifts in the timing of annual peak biomass from early May to late July (Mackas *et al*. 1998). From late summer through autumn, *N. plumchrus* migrate to deep water ranging from 200-2000 m depending on location within the GOA (Mackas *et al.* 1998). The three right whales caught under scientific permit on 22 August 1961 south of Kodiak Island had all consumed *N. plumchrus* (*Calanus plumchrus*: Omura *et al*. 1969),

potentially by targeting areas where adult copepods remained above 200 m (e.g. Baumgartner *et al.* 2003a).

CRITICAL HABITAT: ALTERNATIVES FOR DISCUSSION

Following the process used by NMFS and other agencies for other taxa, we address below questions concerning the area occupied by North Pacific right whales (at the time of listing), and the physical and biological features that may be essential to the species' conservation. We then present the results of distribution analyses as a basis for subsequent discussions of CH.

What is the area occupied by the species?

As noted above, the overall range of the North Pacific right whale is from about 40º N to 60º N. Whether right whales migrate south of 40º N in winter is not clear. Based upon our review, the general regions which should be considered in any CH analysis for the eastern North Pacific are the western Gulf of Alaska (the shelf and slope waters south of Kodiak) and the southeastern Bering Sea; portions of these regions clearly represent regularly utilized feeding grounds for the remaining population, and were also important at and prior to the time of listing. However, because of recent survey effort in the southeastern Bering Sea, our knowledge of right whales there is much better than in the Gulf of Alaska.

What are the physical and biological features essential to conservation?

First, we note that it is impossible to describe CH for North Pacific right whale breeding/calving areas because the location of these grounds remains completely unknown. Accordingly, this assessment focuses exclusively on the feeding grounds.

For the purpose of this assessment, we consider PCEs for North Pacific right whale CH to be the species of large copepods on which they are known or believed to feed. In particular, these include but are not necessarily limited to: *Calanus marshallae, Neocalanus cristatus* and *N. plumchris.* In addition*, Thysanoëssa raschii* is a copepod whose very large size, high lipid content and occurrence in the region likely makes it a preferred prey item for right whales (J. Napp, pers. comm.) Accordingly, CH is defined as areas in which the physical and biological oceanography combines to promote high productivity and aggregation of large copepods into patches of sufficient density for right whales, and these features are presumed to be essential for the conservation of the population.

As noted above, right whales require - and are very efficient at locating - copepod patches of very high density, and these are typically small and widely scattered in space and time. Because of this constraint, typical zooplankton sampling is too broad-scale in nature to detect patches of these densities, and directed studies employing fine-scale sampling cued by the presence of feeding right whales are the only means of doing this. Accordingly, there may be no obvious correlation between the abundance and distribution of copepods (as measured by broad-scale oceanographic sampling) and the distribution of right whales (M. Baumgartner, in prep.)

In light of this, we must rely upon the whales themselves to indicate the location of important feeding areas in the North Pacific. Therefore, in the absence of the appropriate data on the PCEs themselves, the distribution of right whales is used here as a proxy for the existence of suitably dense copepod patches and thus to help identify possible candidates for CH.

More specifically, we have focused on areas in which right whales have been observed to aggregate consistently, rather than where they have appeared singly or in low numbers, or in transit. In some cases (such as portions of the southeastern Bering Sea), we have been able to substantiate this assumption with observations of feeding behavior, or records of stomach contents of dead whales. These assumptions underlie the recommendations given below. It is not clear whether the area immediately south of the Aleutian Islands represents a feeding ground, very little survey effort has occurred there in recent years.

ASSESSMENTS BY AREA

Approach

The entire data set on right whale distribution summarized above represents numerous sightings spread over various parts of the Southeastern Bering Sea and Gulf of Alaska; some of these sightings are clearly concentrated, while others are more scattered outside the areas of core distribution. In order to identify areas that may be of particular importance to right whales as feeding grounds (referred to here as "areas of concentration"), we adopted the following approach in our analysis of the data.

In the first step, data sets containing right whale encounters made as close as possible to the time of ESA listing (1972) were plotted (Figure 1). For the Southeastern Bering Sea, this included Japanese sighting data (1941-1968) and Soviet illegal whaling data (1964 and 1967). For the Gulf of Alaska, this included Japanese sighting data (1941-1968) and Soviet illegal whaling data (1963-1966).[3] Next, all observations in the post-listing period were plotted, including research sightings and acoustic detections since 1982 and 1979, respectively (Figure 2). As noted above, since there was no marked difference in general distribution between the two periods, the entire combined data set (1941-2004) was used for the purpose of analysis (Figure 3).

In the second step, a density plot of these sightings was generated (Figure 4). To create this plot, a circular search area was applied to each region (in this case 0.05 mile cells). The search area, set at 1 mile, determined the distance to search for right whale encounters in order to calculate the density value for these 0.05 mile cells. We used a kernel density calculation which weighs the encounters lying near the center of the cell's search area more heavily than those lying near the edges; this provided a smoother distribution of values compared to using a simple density calculation (though visually the two techniques yielded similar results when mapped). This technique provided a density

[3]The locations of all Soviet catches are taken directly from the unnumbered figure on page 100 of Doroshenko (2000). Since individual catch records are no longer available, the accuracy of Doroshenko's plots are unclear. This is an important caveat, since these catch locations drive much of the density plots generated in the present document. While the plotted locations of the Soviet catches are certainly consistent with what is known of the distribution of North Pacific right whales in the Bering Sea and Gulf of Alaska, neither the accuracy nor precision of the data on which they are based have been established.

surface for the right whale encounters, showing where they were more highly concentrated in the Southeastern Bering Sea, along the Aleutian Islands and in the Gulf of Alaska. In the final step of the analysis, we focused on regions spreading from the area of highest density, excluding low-density patches or patches which were peripheral to the core distribution (unless stated otherwise below).

Assessment: Southeastern Bering Sea

The area of densest concentration of right whales in the Southeastern Bering Sea (Figure 4) spreads roughly east from 173°W longitude to 161°W longitude and south from 58°N latitude. Right whale encounters totaled 474 within this area, out of the 504 encounters north of the Aleutian Islands. This represents 91% of all encounters. Comparing pre-listing to post-listing totals yields similar results: 94% of pre-listing sightings (291 of 320) and 99% of post-listing encounters (183 of 184) occur within this region of densest concentration.

Assessment: Gulf of Alaska

The area of densest concentration of right whales in the Gulf of Alaska (Figure 4) spreads roughly east from 170°W longitude to 150°W longitude and south to 52°N latitude. Right whale encounters within this area of concentration totaled 385 of the 426 encounters in the Gulf. This represents 90% of all encounters. Comparing pre-listing to post-listing totals yields similar results: 90% of pre-listing sightings (373 of 413) and 92% of post-listing encounters (12 of 13) occur within this region of densest concentration.

LITERATURE CITED

Aguilar, A. 1986. A review of old Basque whaling and its effect on the right whales of the North Atlantic. *Rep. int. Whal. Commn*, Special Issue 10: 191-199.

Angliss, R.P. and Lodge, K.L. 2004. Alaska Marine Mammal Stock Assessments, 2003. NOAA Technical Memorandum NMFS-AFSC-144, pp. 172-175.

Baumgartner, M.F. & Mate, B.R. (2003) Summertime foraging ecology of North Atlantic right whales. Marine Ecology Progress Series, 264, 123-135.

Baumgartner, M.F., Cole, T.V.N., Clapham, P.J. & Mate, B.R. (2003a) North Atlantic right whale habitat in the lower Bay of Fundy and on the SW Scotian Shelf during 1999-2001. Marine Ecology Progress Series, 264, 137-154.

Baumgartner, M.F., Cole, T.V.N., Campbell, R.G., Teegarden, G.J. & Durbin, E.G. (2003b) Associations between North Atlantic right whales and their prey, Calanus finmarchicus, over diel and tidal time scales. Marine Ecology Progress Series, 264, 155-166.

Brown, C.W. & Winn, H.E. (1989) Relationship between the distribution pattern of right whales, Eubalaena glacialis, and satellite-derived sea surface thermal structure in the Great South Channel. Continental Shelf Research, 9, 247-260.

Brownell, R.L. Jr., Clapham, P.J., Miyashita, T. & Kasuya. T. 2001. Conservation status of North Pacific right whales. *Journal of Cetacean Research and Management*, Special Issue 2: 269-286.

Clapham, P., Good, C., Quinn, S., Reeves, R.R., Scarff, J.E, & Brownell, R.L. Jr. 2004.

Distribution of North Pacific right whales (*Eubalaena japonica)* as shown by 19th and 20th century whaling catch and sighting records. *Journal of Cetacean Research and Management* 6: 1-6.

Clapham, P.J., Young, S.B. & Brownell, R.L. Jr. 1999. Baleen whales: conservation issues and the status of the most endangered populations. *Mammal Review* 29: 35-60.

Coachman, L.K. (1986) Circulation, water masses and fluxes on the southeastern Bering Sea shelf. Continental Shelf Research, 5, 23-108.

Cooney, R.T. (1986) The seasonal occurrence of Neocalanus cristatus, Neocalanus plumchrus and Eucalanus bungii over the northern Gulf of Alaska. Continental Shelf Research 5, 541-553.

Cooney, R.T. (1987) Zooplankton. In: The Gulf of Alaska: Physical Environment and Biological Resources (Ed. by D.W. Hood & S.T. Zimmerman), pp.285-303. U.S. Ocean Assessment Division, Minerals Management Service publication number, OCS Study MMS 86-0095.

Cooney, R.T. & Coyle, K.O. (1982) Trophic implications of cross-shelf copepod distributions in the southeastern Bering Sea. Marine Biology, 70, 187-196.

Coyle, K.O. (in press) Zooplankton distribution, abundance and biomass relative to water masses in eastern and central Aleutian Island passes. Fisheries Oceanography

Coyle, K.O. & Pinchuk, A.I. (2002) Climate-related differences in zooplankton density and growth on the inner shelf of the southeastern Bering Sea. Progress in Oceanography, 55, 177-194.

Coyle, K.O. & Pinchuk, A.I. (2003) Annual cycle of zooplankton abundance, biomass and production on the northern Gulf of Alaska shelf, October 1997 through October 2000. Fisheries Oceanography, 12, 327-338

Doroshenko, N.V. 2000. Soviet whaling for blue, gray, bowhead and right whales in the North Pacific Ocean, 1961-1979. Pp. 96-103 in *Soviet Whaling Data (1949-1979)*. Center for Russian Environmental Policy, Moscow.

Flint, M.V., Sukhanova, I.N., Kopylov, A.I., Poyarkov S.G. & Whitledge, T.E. (2002) Plankton distribution associated with frontal zones in the vicinity of the Pribilof Islands. Deep-Sea Research II, 49, 6069-6094.

Frost, B.W. (1974) Calanus marshallae, a new species of calanoid copepod closely allied to the sibling species C. finmarchicus and C. glacialis. Marine Biology, 26, 77-79.

Gaines, C.A., Hare, M.P., Beck, S.E. and Rosenbaum, H.C. 2005. Nuclear markers confirm taxonomic status and relationships among highly endangered and closely related right whale species. *Proc. R. Soc. B* 272: 533-542.

Goddard, P.D. & Rugh, D.J. (1998) A group of right whales seen in the Bering Sea in July 1996. Marine Mammal Science, 14, 344-349.

Hamilton, P.K., A.R. Knowlton, M.K. Marx, and S.D. Kraus. 1998. Age structure and longevity in North Atlantic right whales *Eubalaena glacialis* and their relation to reproductions. Marine Ecology Progress Series 171:285-292

Hunt, G.L., Jr., Baduini, C. & Jahncke, J. (2002a) Diets of short-tailed shearwaters in the southeastern Bering Sea. Deep-Sea Research II, 49, 6147-6156.

Hunt, G.L., Stabeno, P., Walters, G., Sinclair, E., Brodeur, R.D., Napp, J.M. & Bond, N.A. (2002b) Climate change and control of the southeastern Bering Sea pelagic ecosystem. Deep-Sea Research II, 49, 5821-5853.

Kenney, R.D. 2002. North Atlantic, North Pacific, and Southern right whales. Pp. 806-813 in Encyclopedia of Marine Mammals (W.F. Perrin, B. Wursig, J.G.M. Thewissen, editors). Academic Press, 1414p.

Klumov, S.K. (1962) The right whales in the Pacific Ocean (Gladkie (Yaponskie) kity tikhogo okeana). Trudy Instituta Okeanologii, 58, 202-297 [transl. available at the National Marine Mammal Laboratory Library, 7600 Sand Point Way NE, Seattle, WA].

Klumov, S.K. (1963) Food and helminth fauna of whalebone whales (Mystacoceti) in the main whaling regions of the world oceans. Trudy Instituta Okeanologii, 71, 94-194 [transl. by Th. Pidhayny, Fisheries Research Board of Canada Translation Series No. 589, 1965].

Kraus, S., Hamilton, P., Kenney, R., Knowlton, A. and Slay, C. 2001. Reproductive parameters of the North Atlantic right whale (*Eubalaena glacialis*). *J. Cetacean Res. Manage*. (Special Issue) 2: 231-236.

Kraus, S.D., Prescott, J.H., Knowlton, A.R. and Stone, G.S. 1986. Migration and calving of right whales (*Eubalaena glacialis*) in the western North Atlantic. *Rep. int. Whal. Commn.* (special issue) 10: 139-144.

Ladd, C., Hunt, Jr. G., Mordy, C., Salo, S. & Stabeno, P. (in press) Marine environment of the eastern and central Aleutian Islands. Fisheries Oceanography

Livingston, P.A., Low, L-L. & Marasco, R.J. (1999) Eastern Bering Sea ecosystem trends. In: Large marine ecosystems of the Pacific Rim: assessment, sustainability, and management (Ed. by K. Sherman & Q. Tang), pp. 140-162. Blackwell Science, Inc. Malden, MA.

Mackas, D.L., Goldblatt, R. & Lewis A.G. (1998) Interdecadal variation in the developmental timing of Neocalanus plumchrus populations at Ocean Station P in the subarctic North Pacific. Canadian Journal of Fisheries and Aquatic Sciences, 55, 1878-1893.

Mate, B.R., Nieukirk, S.L. & Kraus, S.D. (1997) Satellite-monitored movements of the northern right whale. Journal of Wildlife Management, 61, 1393-1405.

Maury. M.F. 1853. A chart showing the favorite resort of the sperm and right whale by M.F. Maury, LLD Lieut. US Navy. Constructed from Maury's whale chart of the world, by Robt. H. Wyman, Lieut. USN by Authority of Commo. Charles Morris USN Chief of Bureau of Ordnance and Hydrography. Washington, 1 sheet.

Miller, C.B. & Nielsen, R.D. (1988) Development and growth of large, calanid copepods in the Ocean Subarctic Pacific, May 1984. Progress in Oceanography, 20, 275-292.

Miller, C.B. & Clemons, M.J. (1988) Revised life history analysis for large grazing copepods in the subarctic Pacific Ocean. Progress in Oceanography, 20, 293-313.

Mizobata, K., Saitoh, S.I., Shiomoto, A., Miyamura, T., Shiga, N., Imai, K., Toratani, M., Kajiwara, Y. & Sasaoka, K. (2002) Bering Sea cyclonic and anticyclonic eddies observed during summer 2000 and 2001. Progress in Oceanography, 55, 65-75.

Moore, S.E., Waite, J.M., Friday, N.A. & Honkalehto, T. (2002) Cetacean distribution and relative abundance on the central-eastern and the southeastern Bering Sea shelf with reference to oceanographic domains. Progress in Oceanography, 55, 249-261.

Napp, J.M., Baier, C.T., Brodeur, R.D., Coyle, K.O., Shiga, N. & Mier, K. (2002) Interannual and decadal variability in zooplankton communities of the southeast Bering Sea shelf. Deep-Sea Research II, 49, 5991-6008.

Napp, J.M., Kendall, A.W. & Schumacher, J.D. (2000) A synthesis of biological and

physical processes affecting the feeding environment of larval walleye pollock (Theragra chalcogramma) in the eastern Bering Sea. Fisheries Oceanography, 9, 147-162.

NMFS. 1991. Final Recovery Plan for the Northern Right Whale, *Eubalaena glacialis.* U.S. Department of Commerce, national Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources. 86 pp.

Okkonen, S.R. (2001) Altimeter observations of the Bering Slope Current eddy field. Journal of Geophysical Research, 106, 2465-2476.

Okkonen, S.R., Jacobs, G.A., Metzger, E.J., Hurlburt, H.E. & Shriver, J.F. (2001) Mesoscale variability in the boundary currents of the Alaska Gyre. Continental Shelf Research, 21, 1219-1236.

Omura, H. (1958) North Pacific right whale. Scientific Report of the Whales Research Institute, Tokyo, 13, 1-52.

Omura, H., Ohsumi, S., Nemoto, R., Nasu, K. & Kasuya, T. (1969) Black right whales in the North Pacific. Scientific Report of the Whales Research Institute, Tokyo, 21, 1-78.

Pace, R.M. and Merrick, R.L. 2005. Potential Primary Constituent Elements for right whales (*Eubalaena glacialis*) in the northwest Atlantic Ocean. Document available from Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543.

Rosenbaum, H.C., Brownell, R.L. Jr., Brown, M.W., Schaeff, C., Portway, V., White, B.N., Malik, S., Pastene, L.A., Patenaude, N.J., Baker, C.S., Goto, M., Best, P.B., Clapham, P.J., Hamilton, P., Moore, M., Payne, R., Rowntree, V., Tynan, C.T. & DeSalle, R. 2000. Worldwide genetic differentiation of *Eubalaena*: questioning the number of right whale species. *Molecular Ecology* 9: 1793-1802.

Royer, T.C., Hansen, D.V. & Pashinski, D.J. (1979) Coastal flow in the northern Gulf of Alaska as observed by dynamic topography and satellite-tracked drogued drift buoys. Journal Physical Oceanography, 9, 785-801.

Scarff, J.E. 1986. Historic and present distribution of the right whale (*Eubalaena glacialis*) in the eastern North Pacific south of 50° N and east of 180°W. *Rep int. Whal. Commn.* (special issue) 10: 43-63.

Scarff, J.E. 1991. Historic distribution and abundance of the right whale (*Eubalaena glacialis*) in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury whale charts. *Rep int. Whal. Commn.* 41: 467-489.

Schumacher, J.D. & Stabeno, P.J. (1998) Continental shelf of the Bering Sea. In: The Sea, Vol 11 (Ed. by Robinson, A.R. & Brink, K.H), pp. 789-822. John Wiley & Sons, New York, NY.

Schumacher, J.D., Kinder, T.H., Pashinski, D.J. & Charnell, R.L. (1979) A structural front over the continental shelf of the eastern Bering Sea. Journal of Physical Oceanography, 9, 79-87.

Schumacher, J.D., Bond, N.A., Brodeur, R.D., Livingston, P.A., Napp, J.M., and Stabeno, P.J. (2003) Climate change in the southeastern Bering Sea and some consequences for biota. In: Large marine ecosystems of the World: trends in exploitation, protection, and research (Ed. by G. Hempel & K. Sherman), pp. 17-40. Elsevier Science, Amsterdam.

Shelden, K.E.W., Moore, S.E., Waite, J.M, Wade, P.R. and Rugh, D.J. 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. *Mammal Rev.* 35: 129-155.

Sinclair, E., Moore, S., Friday, N., Zeppelin, T. & Waite, J. (in press) Physical mechanisms influencing regional distribution and abundance of apex predators: relevance to ecosystem management. Fisheries Oceanography, ### (Special Issue), #-#.

Smith, S.L. & Vidal, J. (1986) Variations in the distribution, abundance, and development of copepods in the south-eastern Bering Sea in 1980 and 1981. Continental Shelf Research, 5 (1/2), 215-239.

Springer, A.M., McRoy, C.P. & Flint, M.V. (1996) The Bering Sea green belt: shelf-edge processes and ecosystem production. Fisheries Oceanography, 5, 205-223.

Stabeno, P.J. & Hunt, Jr., G.L. (2002) Overview of the inner front and southeast Bering Sea carrying capacity programs. Deep-Sea Research II, 49, 6157-6168.

Stabeno, P.J., Kachel, D.G., Kachel, N.B. & Sullivan, M.E. (in press) Observations from moorings in the Aleutian Passes: temperature, salinity and transport. Fisheries Oceanography.

Townsend, C.H. 1935. The distribution of certain whales as shown by the logbook records of American whaleships. *Zoologica* 19: 1-50.

Tynan, C.T. (1998) Critical habitat and abundance estimation of right whales in the southeast Bering Sea. Paper SC/50/CAWS18 presented to the IWC Scientific Committee, April 1998 [Available from International Whaling Commission, The Red House, 135 Station Road, Impington, Cambridge, CB4 9NP, UK].

Tynan, C.T., DeMaster, D.P. & Peterson, W.P. (2001) Endangered right whales on the southeastern Bering Sea shelf. Science, 294, 1894.

Tynan, C.T. (2004) Cetacean populations on the southeastern Bering Sea shelf during the late 1990s: implications for decadal changes in ecosystem structure and carbon flow. Marine Ecology Progress Series, 272, 281-300.

Vidal, J. & Smith, S.L. (1986) Biomass, growth and development of populations of herbivorous zooplankton in the southwestern Bering Sea during spring. Deep-Sea Research, 33, 523-556.

Webb, R.L. 1988. *On the Northwest Ground: commercial whaling in the Pacific Northwest 1790-1967.* Univ. of British Columbia Press, Vancouver. 425 pp.